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The gene encoding TPO has been cloned and characterized. See Kuter et al. Proc. Natl. Acad. Sci. USA

91:11104-11108 1994 ; Barley et al. Cell **77:1117-1124**

1994 ; Kaushansky et al. Nature **369:568-571** 1994 ; Wendling

8 et al. Nature **369:571-574** 1994 ; and Sauvage et al. Nature

369:533-538 (1994) . Thrombopoietin is a glycoprotein with at

least two forms, with apparent molecular masses of 25 kDa and

31 kDa, with a common N-terminal amino acid sequence. See,

Bartley et al. Cell **77:1117-1124** 1994 . Thrombopoietin

10 appears to have two distinct regions separated by a potential

Arg-Arg cleavage site. The amino-terminal region is highly

conserved in man and mouse, and has some homology with

erythropoietin and interferon-a and interferon-b. The

carboxy-terminal region shows wide species divergence.

15 The DNA sequences and encoded peptide sequences for

human TPO-R (also known as c-mpl) have been described. See

Vigon et al. Proc. Natl. Acad. Sci. USA **89:5640-5644** (1992).

TPO-R is a member of the haematopoietin growth factor

receptor family, a family characterized by a common structural

20 design of the extracellular domain, including four conserved C

residues in the N-terminal portion and a WSXWS motif (SEQ ID

NO:1) close to the transmembrane region. See Baran Proc.

Natl. Acad. Sci. USA **87:6934-6938** (1990). Evidence that this

receptor plays a functional role in hematopoiesis includes

25 observations that its expression is restricted to spleen, bone

marrow, or fetal liver in mice (see Souyri et al. Cell

63:1137-1147 (1990)) and to megakaryocytes, platelets, and

CD34⁺ cells in humans (see Methia et al. Blood **82:1395-1401**

(1993)). Furthermore, exposure of CD34⁺ cells to synthetic

30 oligonucleotides antisense to mpl RNA significantly inhibits

the appearance of megakaryocyte colonies without affecting

erythroid or myeloid colony formation. Some workers postulate

that the receptor functions as a homodimer, similar to the

situation with the receptors for G-CSF and erythropoietin.

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in
independently selected from any of the 11 genetically related

having from 1 to 3 substituents on the phenyl ring selected from the group consisting of lower alkyl, lower alkoxy, chloro, and bromo, where R and R¹ are independently selected from the group consisting of hydrogen and lower alkyl,

and still further wherein the C-terminus of said peptide or peptide mimetic has the formula $-C(=O)R^2$ where R² is selected from the group consisting of hydroxy, lower alkoxy, and $-NR^3R^4$ where R³ and R⁴ are independently selected from the group consisting of hydrogen and lower alkyl and where the nitrogen atom of the $-NR^3R^4$ group can optionally be the amine group of the N-terminus of the peptide so as to form a cyclic peptide,

and physiologically acceptable salts thereof.

In a related embodiment, the invention is directed to a labeled peptide or peptide mimetic comprising a peptide or peptide mimetic described as above having covalently attached thereto a label capable of detection.

In some embodiments of the invention, preferred peptides for use include peptides having a core structure comprising a sequence of amino acids (SEQ ID NO:2):

$$X_1 X_2 X_3 X_4 X_5 X_6 X_7$$

where X₁ is C, L, M, P, Q, V; X₂ is F, K, L, N, Q, R, S, T or V; X₃ is C, F, I, L, M, R, S, V or W; X₄ is any of the 20 genetically coded L-amino acids; X₅ is A, D, E, G, K, M, Q, R, S, T, V or Y; X₆ is C, F, G, L, M, S, V, W or Y; and X₇ is C, G, I, K, L, M, N, R or V.

In a preferred embodiment the core peptide comprises a sequence of amino acids (SEQ ID NO:3):

$$X_1 G X_2 X_3 X_4 X_5 X_6 X_7$$

where X₁ is L, M, P, Q, or V; X₂ is F, R, S, or T; X₃ is F, L, V, or W; X₄ is A, K, L, M, R, S, V, or T; X₅ is A, E, G, K, M, Q, R, S, or T; X₆ is C, I, K, L, M or V; and each X₇ residue is independently selected from any of the 20 genetically coded L-amino acids, their stereoisomeric D-amino acids; and non-natural amino acids. Preferably, each X₇ residue is independently selected from any of the 20 genetically coded

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L-amino acids and their stereoisomeric L-amino acids. In a preferred embodiment SEQ ID NO:4, X_1 is F; X_2 is T; X_3 is L; X_4 is R; X_5 is E or Q; and X_6 is I or L.

More preferably, the core peptide comprises a sequence of amino acids (SEQ ID NO:5):

$X_1 X_2 G X_3 X_4 X_5 X_6 W X_7$

where X_1 is A, C, E, G, I, L, M, F, R, D, S, T, or V; and X_2 is A, C, D, E, K, L, Q, R, S, T, or V. More preferably, X_1 is A or I; and X_2 is D, E, or K.

Particularly preferred peptides include (SEQ ID NOS 6-13, respectively): G G C A D G P T L R E W I S F C G G; G N A D G P T L R Q W L E G R R P K N; G G C A D G P T L R E W I S F C G G K; T I K G P T L R Q W L K S R E H T S; S I E G P T L R E W L T S R T P H S; L A I E G P T L R Q W L H G N G R D T; C A D G P T L R E W I S F C; and I E G P T L R Q W L A A R A.

In further embodiments of the invention, preferred peptides for use in this invention include peptides having a core structure comprising a sequence of amino acids (SEQ ID NO:14):

$C X_1 X_2 X_3 X_4 X_5 X_6$

where X_1 is F, K, L, N, Q, R, S, T or V; X_2 is C, F, I, L, M, R, S or V; X_3 is any of the 20 genetically coded L-amino acids; X_4 is A, D, E, G, S, V or Y; X_5 is C, F, G, I, M, S, V, W or Y; and X_6 is C, G, I, K, L, N, R or V. In a more preferred embodiment, X_1 is A, E, G, H, K, L, M, F, Q, R, S, T, or W. In a further embodiment, X_2 is S or T; X_3 is L or R; X_4 is R; X_5 is D, E, or G; X_6 is F, L, or W; and X_7 is I, K, L, R, or V. Particularly preferred peptides include (SEQ ID NO:15): G G C T L R E W L H G G F C G G.

In a further embodiment, preferred peptides for use in this invention include peptides having a structure comprising a sequence of amino acids (SEQ ID NO:16):

$X_1 C X_2 X_3 X_4 X_5 X_6$

where X_1 is F, K, L, N, Q, R, S, T or V; X_2 is C, E, I, L, M, R, S, V or W; X_3 is any of the 20 genetically coded L-amino acids; X_4 is A, D, E, G, K, M, Q, R, S, T, V or Y; X_5 is C, E, G, L, M, S, V, W or Y; X_6 is C, G, I, K, L, M, N, P or V; and X_7 is any of the 20 genetically coded L-amino acids. In some embodiments, X_1 is preferably G, S, V, or R.

The compounds described herein are useful for the prevention and treatment of diseases mediated by TPO, and particularly for treating hematological disorders, including but not limited to, thrombocytopenia resulting from chemotherapy, radiation therapy, or bone marrow transfusions.

Thus, the present invention also provides a method for treating wherein a patient having a disorder that is susceptible to treatment with a TPO agonist receives, or is administered, a therapeutically effective dose or amount of a compound of the present invention.

The invention also provides for pharmaceutical compositions comprising one or more of the compounds described herein and a physiologically acceptable carrier. These pharmaceutical compositions can be in a variety of forms including oral dosage forms, as well as inhalable powders and solutions and injectable and infusible solutions.

BRIEF DESCRIPTION OF THE FIGURES

Figures 1A-B illustrates the results of a functional assay in the presence of various peptides; the assay is described in Example 1. Figure 1A is a graphical depiction of the results of the TPO-R transfected Ba F3 cell proliferation assay for selected peptides of the invention:

■ designating the results for (SEQ ID NO:8) G G C A T G P T L R E W I S F C G G K (biotin);

X designating the results for (SEQ ID NO:8) G G C A T G P T L R E W I S F C G G;

▲ designating the results for SEQ ID NO:11 L A L E G
P T L R Q W L H G N G E D T;

○ designating the results for SEQ ID NO:7 G H A D G
P T L R Q W L E G P R E K N; and

● designating the results for SEQ ID NO:9 T I K S E
T L R Q W L K S R E H T S.

Figure 1B is a graphical depiction of the results
with the same peptides and the parental cell line.

Figure 2A-C show the results of peptide
10 oligomerization using the TPO-R transfected Ba/F3 cell
proliferation assay. Figure 2A shows the results of the assay
for the complexed biotinylated peptide (AF 12285 with
streptavidin (SA)) for both the transfected and parental cell
lines. Figure 2B shows the results of the assay for the free
15 biotinylated peptide (AF 12285) for both the transfected and
parental cell lines. Figure 2C shows the results of the assay
for streptavidin alone for both the transfected and parental
cell lines.

Figures 3A-G show the results of a series of control
20 experiments showing the activity of TPO, the peptides of the
present invention, EPO, and EPO-R binding peptides in a cell
proliferation assay using either the TPO-R transfected Ba/F3
cell line and its corresponding parental line, or an
EPO-dependent cell line. Figure 3A depicts the results for
25 TPO in the cell proliferation assay using the TPO-R
transfected Ba/F3 cell line and its corresponding parental
line. Figure 3B depicts the results for EPO in the cell
proliferation assay using the TPO-R transfected Ba/F3 cell
line and its corresponding parental line. Figure 3C depicts
30 the results for complexed biotinylated peptide (AF 12285 with
streptavidin (SA)) and a complexed form of a biotinylated
EPO-R binding peptide (AF 11305 with SA) in the TPO-R
transfected Ba/F3 cell line. The results for the
corresponding parental cell line are shown in Figure 3D.
35 Figure 3E depicts the results for TPO in the cell

proliferation assay using the EPC-dependent cell line. Figure 3F depicts the results for EPC in the cell proliferation assay using the EPC-dependent cell line. Figure 3G depicts the results for complexed biotinylated peptide AF 11415 with streptavidin SA and the complexed film of a biotinylated EPC-R binding peptide AF 11515 with SA in the EPC-dependent cell line.

Figures 4A-C illustrates the construction of peptides-on-plasmids libraries in vector pJS142. Figure 4A shows a restriction map and position of the genes. The library plasmid includes the *rrnB* transcriptional terminator, the *bla* gene to permit selection on ampicillin, the M13 phage intragenic region (M13 IG) to permit rescue of single-stranded DNA, a plasmid replication origin (*ori*), two *lacO_s* sequences, and the *araC* gene to permit positive and negative regulation of the *araB* promoter driving expression of the *lac* fusion gene. Figure 4B (SEQ ID NOS 19 & 20, respectively) shows the sequence of the cloning region at the 3' end of the *lac I* gene, including the *SfiI* and *EagI* sites used during library construction. Figure 4C (SEQ ID NOS 223 & 224, respectively) shows the ligation of annealed library oligonucleotides, ON-829 and ON-830, to *SfiI* sites of pJS142 to produce a library. Single spaces in the sequence indicate sites of ligation.

Figures 5A-B illustrate cloning into the pELM3 and pELM15 MBP vectors. Figure 5A (SEQ ID NOS 225 & 226, respectively) shows the sequence at the 3' end of the *malE* fusion gene, including the MBP coding sequence, the poly asparagine linker, the factor Xa protease cleavage site, and the available cloning sites. The remaining portions of the vectors are derived from pMALc2 (pELM3) and pMALp2 (pELM15), available from New England Biolabs. Figure 5B (SEQ ID NOS 227 & 228, respectively) shows the sequence of the vectors after transfer of the BspEII-ScaI library fragment into *AgeI*-*ScaI* digested pELM3, pELM15. The transferred sequence includes the

11a
sequence encoding the GGG peptide linker from the pJ6142
library.

Figure 6A depicts a restriction map and position of the genes for the construction of headpiece dimer libraries in vector pCMG14. The library plasmid includes: the *rrnB* transcriptional terminator, the *bla* gene to permit selection on ampicillin, the M13 phage intragenic region M13 IG to permit rescue of single-stranded DNA, a plasmid replication origin (*ori*), one *lacO*, *s*sequence, and the *araC* gene to permit positive and negative regulation of the *araB* promoter driving expression of the headpiece dimer fusion gene. Figure 6B (SEQ ID NOS 229 & 230, respectively) depicts the sequence of the cloning region at the 3' end of the headpiece dimer gene, including the *SfiI* and *EagI* sites used during library construction. Figure 6C (SEQ ID NOS 231 & 232, respectively) shows the ligation of annealed ON-1679, ON-829, and ON-830 to *SfiI* sites of pCMG14 to produce a library. Singles spaces in the sequence indicate sites of ligation.

Figures 7 to 9 show the results of further assays evaluating activity of the peptides and peptide mimETICS of the invention. In this assay mice are made thrombocytopenic with carboplatin. Figure 7 depicts typical results when Balb/C mice are treated with carboplatin (125 mg/kg intraperitoneally) on Day 0. The dashed lines represent untreated animals from three experiments. The solid line represent carboplatin-treated groups in three experiments. The heavy solid lines represent historical data. Figure 8 depicts the effect of carboplatin titration on platelet counts in mice treated with the indicated amounts of carboplatin (in mg/kg, intraperitoneally, ip) on Day 0. Figure 9 depicts amelioration of carboplatin-induced thrombocytopenia on Day 10 by peptide AF12513 (513). Carboplatin (CBP; 50-125 mg/kg, intraperitoneally) was administered on Day 0. AF12513 (1 mg/kg, ip) was given on Days 1-9.

the consensus sequence mutagenized at 70:10:10:10 frequency and extended on each terminus with random residues to produce clones which encode the sequence (SEQ ID NO:21 XXXXX C, S, P, or R TLPEWL XXXXXXXX C or S). A similar
5 extended/mutagenized library was constructed using the peptides-on-plasmids system to produce clones which encode the sequence (SEQ ID NO:22 XXXXXX C, S, P, or R TLPEWL XXXXXXXX. An additional extended/mutagenized library (SEQ ID NO:23, XXXXX C, S, P, or R TLPEWL XXXXXXXX C or S, was
10 constructed using the polysome display system. All three libraries were screened with peptide elution and probed with radiolabeled monovalent receptor.

The "peptides on plasmids" techniques was also used for peptide screening and mutagenesis studies and is described
15 in greater detail in U.S. Patent no. 5,338,665, which is incorporated herein by reference for all purposes. According to this approach, random peptides are fused at the C-terminus of LacI through expression from a plasmid vector carrying the fusion gene. Linkage of the LacI-peptide fusion to its
20 encoding DNA occurs via the lacO sequences on the plasmid, forming a stable peptide-LacI-plasmid complex that can be screened by affinity purification (panning) on an immobilized receptor. The plasmids thus isolated can then be reintroduced into *E. coli* by electroporation to amplify the selected
25 population for additional rounds of screening, or for the examination of individual clones.

In addition, random peptide screening and mutagenesis studies were performed using a modified C-terminal Lac-I display system in which display valency was reduced
30 ("headpiece dimer" display system). The libraries were screened and the resulting DNA inserts were cloned as a pool into a maltose binding protein (MBP) vector allowing their expression as a C-terminal fusion protein. Crude cell lysates from randomly picked individual MBP fusion clones were then
35 assayed for TPO-R binding in an ELISA format, as discussed above.

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Peptide mutagenesis studies were also conducted using the polysome display system, as described in co-pending application U.S. Patent Application Serial No. 08/300,262, filed September 1, 1994, which is a continuation-in-part application based in U.S. Patent Application Serial No. 08/144,775, filed October 29, 1993 and PCT WO 93/11992, each of which is incorporated herein by references for all purposes. A mutagenesis library was constructed based on the sequence (SEQ ID NO:24) X X X X C, E, E, or S. e l r e f l X X X X X X X (C or S), in which X represents a random NNK codon, and the lower case letters represent amino acid codons containing 70:10:10:10 mutagenesis at positions 1 and 2 and K (G or T) at position 3 of the codon. The library was panned for 5 rounds against TPO receptor which had been immobilized on magnetic beads. After the fifth round, the PCR amplified pool was cloned into pAFF6 and the ELISA positive clones were sequenced. The sequences were subcloned into an MBP vector and their binding affinities were determined by an MBP ELISA.

To immobilize the TPO-R for polysome screening, Ab 179 was first chemically conjugated to tosyl-activated magnetic beads (available from Dynal Corporation) as described by the manufacturer. The beads were incubated with antibody in 0.5 M borate buffer (pH 9.5) overnight at room temperature. The beads were washed and combined with TPO-R containing the "HPAP" tail. The antibody coated beads and receptor were incubated for 1 hour at 4°C, and the beads were washed again prior to adding the polysome library.

Screening of the various libraries described above yielded the TPO receptor binding peptides shown in Tables 1 and 2 below, as well as others not listed herein.

16

TABLE 1

SEQ ID NOS 25-54, RESPECTIVELY

Peptide																			
R	E	G	P	T	L	R	L	W	N										
R	E	G	P	T	L	R	Q	W	N										
S	R	G	M	T	L	R	E	W	L										
E	G	P	T	L	R	G	W	L	A										
R	E	G	Q	T	L	K	E	W	L										
E	R	G	P	F	W	A	K	A	C										
R	E	G	P	R	C	V	M	W	M										
C	S	G	L	T	L	R	E	W	L	V	C								
C	L	T	G	P	F	V	T	Q	W	L	Y	E	C						
C	G	E	G	L	T	L	T	Q	W	L	E	H	C						
C	F	A	G	P	T	L	L	E	W	L	T	L	C						
C	F	A	G	P	T	L	L	E	W	L	T	L	C						
C	R	Q	G	P	T	L	T	A	W	L	L	E	C						
C	A	L	G	P	T	L	R	E	W	I	S	F	C						
C	E	L	V	G	P	S	L	M	S	W	L	T	C						
C	G	T	E	G	P	T	L	S	T	W	L	D	C						
C	D	Q	L	G	V	T	L	S	R	W	L	E	C						
S	G	T	G	L	T	L	R	E	W	L	G	S	F	S	L	L	S		
C	P	E	G	P	T	L	L	Q	W	L	K	R	G	Y	S	S	C		
R	G	D	G	P	T	L	S	Q	W	L	Y	S	L	M	I	M	C		
M	V	A	G	P	T	L	R	E	F	I	A	S	L	E	I	H	C		
S	M	Q	G	P	T	F	R	E	W	V	S	N	N	N	V	L	C		
S	V	Q	C	G	P	T	L	R	Q	W	L	A	A	R	N	E	L	S	
G	N	A	D	G	P	T	L	R	Q	W	L	E	G	R	R	E	N	N	
S	V	R	C	G	P	T	L	R	Q	W	L	A	A	R	T	H	L	S	
L	A	I	E	G	P	T	L	R	Q	W	L	E	G	N	G	R	D	T	
E	G	R	V	G	P	T	L	R	E	K	E	T	Q	V	A	T	N	N	
C	A	D	G	P	T	L	R	E	W	I	S	F	C						

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TABLE 2

SEQ ID NOS 59-167, respectively

Peptide
C S I E D I R K R C
C R R S E I L E R C
C T F K Q F L D G C
C T R G E W L R C C
C T L R Q W L Q S C
C T L E E L R A C C
C T F E E L M R L C
C Q R A D L I N F C
C N F N D L L L F C
C T F T E W L H G C
C T L E F M N G C
C S I G E L R R L C
C N I N Q L E S I C
C T M R Q F L V C C
C T F S E W L E R C
C T L H E Y L S G C
C T F E E L L R Q C
C T F E E F V N G C
C S R A D F L A A C
C S C A Q V V Q C C
C T L R Q W I L L S M C
C T L R E W L H G G F C
C T L R A W L M S E T C
C T L R A W L M E S C C
C T F Q V W K L A R N C
C I L R E W L D X R T C
C V L R E W L L X N S C
C I L S E F L A G Q Q C

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synthetic peptides are often preceded by one or two glycine residues. These glycines are not believed to be necessary for binding or activity. Likewise, to mimic the exact sequence of peptides displayed on polysomes, the C-terminal amino acids of the synthetic peptides are often preceded by the sequence M A S. Again, this sequence is not believed to be necessary for binding or activity.

IC₅₀ values are indicated symbolically by the symbols "-", "+", and "++". For examples, those peptides which showed IC₅₀ values in excess of 200 μ M are indicated with a "-". Those peptides which gave IC₅₀ values of less than or equal to 200 μ M are given a "+", while those which gave IC₅₀ values of 500 nm or less are indicated with a "++".

Those peptides which gave IC₅₀ values at or near the cutoff point for a particular symbol are indicated with a hybrid designator, e.g., "+/-". Those peptides for which IC₅₀ values were not determined are listed as "N.D.". The IC₅₀ value for peptides having the structure: (SEQ ID NO:15) G G C T L R E W L H G G F C G G was 500 nm or less. (Note the N-terminal and C-terminal amino acids were preceded by two glycines to recreate the exact sequence displayed by the phage. These glycines are not believed to be necessary for binding or activity.)

TABLE 3

(SEQ ID NOS 6,7,8,9,168,11&10, RESPECTIVELY)

Peptide	Affinity
G G C A D G P T L R E W I S F C G G	++
G N A D G P T L R Q W I E G R E E N	++
G G C A D G P T L R E W I S F C G G K	++
T I K G P T L R Q W I E G R E E N	++
G P T L R Q W I	-
L A I E G P T L R Q W I E G R E E N	++
S I E G P T L R E W I S F C G G	++

The tables above, especially Table 3, illustrate that a preferred core peptide comprises a sequence of amino acids SEQ ID NO:1:

1 X₁ X₂ X₃ X₄ X₅ X₆

where X₁ is C, L, M, P, Q, V; X₂ is F, R, S, T or V; X₃ is C, F, I, L, M, P, S, V or W; X₄ is any of the 20 genetically coded L-amino acids; X₅ is A, C, E, G, K, M, Q, R, S, T, V or Y; X₆ is C, F, G, L, M, S, V, W or Y; and X₇ is C, G, I, K, L, M, N, R or V.

In a preferred embodiment the core peptide comprises a sequence of amino acids (SEQ ID NO:3):

X₁ G X₂ X₃ X₄ X₅ W X₆

where X₁ is L, M, P, Q, or V; X₂ is F, R, S, or T; X₃ is F, L, V, or W; X₄ is A, K, L, M, R, S, V, or T; X₅ is A, E, G, K, M, Q, R, S, or T; X₆ is C, I, K, L, M or V; and each X_i residue is independently selected from any of the 20 genetically coded L-amino acids, their stereoisomeric D-amino acids; and non-natural amino acids. Preferably, each X_i residue is independently selected from any of the 20 genetically coded L-amino acids and their stereoisomeric D-amino acids. In a preferred embodiment (SEQ ID NO:4), X₁ is F; X₂ is T; X₃ is L; X₄ is R; X₅ is E or Q; and X₆ is I or L.

More preferably, the core peptide comprises a sequence of amino acids (SEQ ID NO:5):

X₁ X₂ G X₃ X₄ X₅ X₆ W X₇

where X₁ is A, C, E, G, I, L, M, P, R, Q, S, T, or V; and X₂ is A, C, D, E, K, L, Q, R, S, T, or V. More preferably, X₁ is A or I; and X₂ is D, E, or K.

30 Particularly preferred peptides include (SEQ ID NOS 6-13, RESPECTIVELY): G G C A D G F T L R E W I S F C G G; G N A D G F T L R Q W L E G R R F K N; G G C A D G F T L R E W I S F C G G K; T I K G F T L R Q W L E G R E H T S; S I E G F T L R E W I T S R T P H S; L A I E G F T L R Q W L E G N G R C T; 35 C A D G F T L R E W I S F C; and I E G F T L R Q W L A A R A.

In further embodiments of the invention, preferred peptides for use in this invention include peptides having a core structure comprising sequence of amino acids:
sequence of amino acids SEQ ID NO:14 :

5 C X₁ X₂ X₃ X₄ X₅ X₆

where X₁ is F, K, L, N, Q, R, S, T or V; X₂ is C, F, I, L, M, R, S or V; X₃ is any of the 20 genetically coded L-amino acids; X₄ is A, D, E, G, S, V or Y; X₅ is C, F, G, L, M, S, V, W or Y; and X₆ is C, G, I, K, L, M, N, R or V. In a more
10 preferred embodiment, X₄ is A, E, G, H, K, L, M, P, Q, R, S, T, or W. In a further embodiment, X₁ is S or T; X₂ is L or R; X₃ is R; X₄ is D, E, or G; X₅ is F, L, or W; and X₆ is I, K, L, P, or V. Particularly preferred peptides include (SEQ ID NO:15): G G C T L R E W L H G G F C G G.

15 In a further embodiment, preferred peptides for use in this invention include peptides having a structure comprising a sequence of amino acids (SEQ ID NO:16):

X₁ C X₂ X₃ X₄ X₅ X₆ X₇

20 where X₁ is F, K, L, N, Q, R, S, T or V; X₂ is C, F, I, L, M, R, S, V or W; X₃ is any of the 20 genetically coded L-amino acids; X₄ is A, D, E, G, K, M, Q, R, S, T, V or Y; X₅ is C, F, G, L, M, S, V, W or Y; X₆ is C, G, I, K, L, M, N, R or V; and X₇ is any of the 20 genetically coded L-amino acids. In some
25 embodiments, X₁ is preferably G, S, Y, or R.

Peptides and peptidomimetics having an IC₅₀ of greater than about 100 nM lack sufficient binding to permit use in either the diagnostic or therapeutic aspects of this invention. Preferably, for diagnostic purposes, the peptides
30 and peptidomimetics have an IC₅₀ of about 2 nM or less and, for pharmaceutical purposes, the peptides and peptidomimetics have an IC₅₀ of about 100 nM or less.

The binding peptide sequence also provides a means to determine the minimum size of a TFCR binding compound of
35 the invention. Using the "encoded synthetic library" (ESL) system or the "very large scale immobilized polymer synthesis"
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intraperitoneally was administered on Day 0. AF12813 1 mg/kg, ip was given on Days 1-9. These results show the peptides of the invention can ameliorate thrombocytopenia in a mouse model.

5 In addition, certain peptides of the present invention can be dimerized or oligomerized, thereby increasing the affinity and/or activity of the compounds. To investigate the effect that peptide dimerization/oligomerization has on TPO mimetic potency in cell proliferation assays, a
10 C-terminally biotinylated analog of the peptide (SEQ ID NO:6) G G C A D G P T L R E W I S F C G G was synthesized (SEQ ID NO:8) (G G C A D G P T L R E W I S F C G G K (Biotin)). The peptide was preincubated with streptavidin in serum-free HEPES-buffered RPMI at a 4:1 molar ratio. The complex was
15 tested for stimulation of cell proliferation of TPO-R transfected Ba/F3 cells, as above, alongside free biotinylated peptide and the unbiotinylated parental peptide. Figure 2A shows the results of the assay for the complexed biotinylated peptide (AF 12385 with streptavidin (SA)) for both the
20 transfected and parental cell lines. Figure 2B shows the results of the assay for the free biotinylated peptide (AF 12385) for both the transfected and parental cell lines. Figure 2C shows the results of the assay for streptavidin alone for both the transfected and parental cell lines. These
25 figures illustrate that the pre-formed complex was approximately 10 times as potent as the free peptide.

The specificity of the binding and activity of the peptides of the invention was also examined by studying the cross reactivity of the peptides for the erythropoietin
30 receptor (EPO-R). The EPO-R is also a member of the haematopoietin growth factor receptor family, as is TPO-R. The peptides of the invention, as well as TPO, EPO, and a known EPO-binding peptide, were examined in a cell proliferation assay using an EPO-dependent cell line. This
35 assay utilized FDCP-1, a growth factor dependent murine multi-potential primitive haematopoietic progenitor cell line

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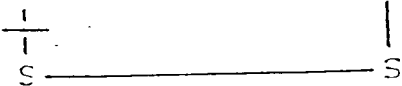


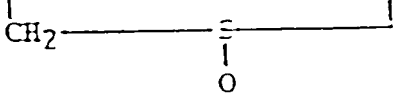
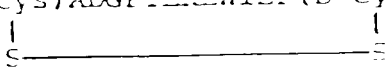
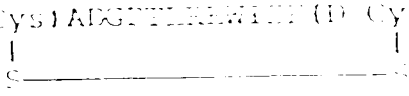
EXAMPLE 4"PEPTIDES ON PLASMIDS"

The pJ8142 vector is used for library construction and is shown in Figure 4. Three oligonucleotide sequences (SEQ ID NOS 169-171, respectively) are needed for library construction: ON-829 (5' ACC ACC TCC GC ; ON-830 (5' TTA CTT AGT TA) and a library specific oligonucleotide of interest (3' GA GGT GGT {NNK}_n TAA CTA AGT AAA GC , where {NNK}_n denotes a random region of the desired length and sequence. The oligonucleotides can be 5' phosphorylated chemically during synthesis or after purification with polynucleotide kinase. They are then annealed at a 1:1:1 molar ratio and ligated to the vector.

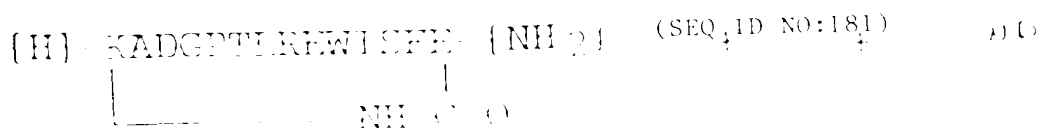
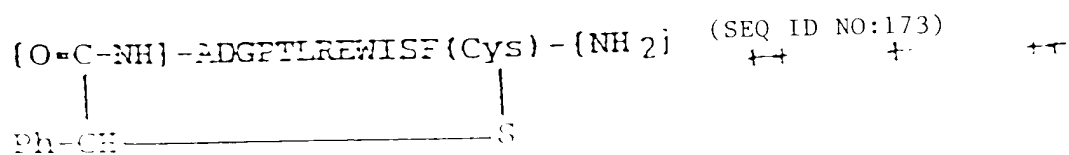
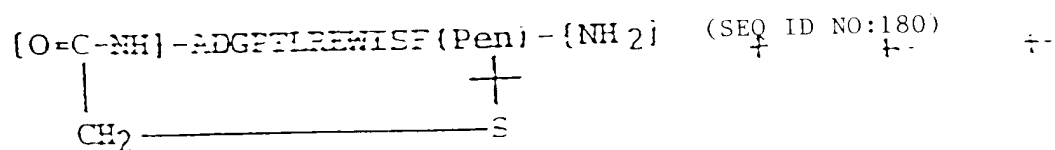
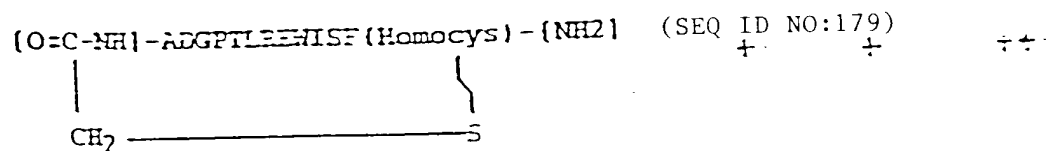
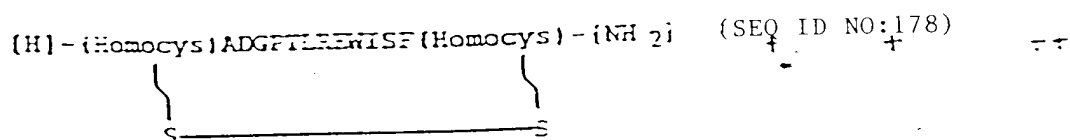
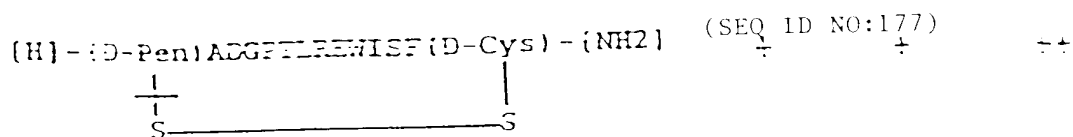
The strain of *E. coli* which is preferably used for panning has the genotype: Δ (*srl-recA*) *endA1 nupG lon-11 sulA1 hsdR17* Δ (*cmpT-fepC*)266 Δ *clpA319::kan* Δ *lacI lac* *ZU118* which can be prepared from an *E. coli* strain from the *E. coli* Genetic Stock Center at Yale University (*E. coli* b/r, stock center designation CGSC:6573) with genotype *lon-11 sulA1*. The above *E. coli* strain is prepared for use in electroporation as described by Dower et al. Nucleic Acids Res. **16:6127** (1988), except that 10% glycerol is used for all wash steps. The cells are tested for efficiency using 1 pg of a Bluescript plasmid (Stratagene). These cells are used for growth of the original library and for amplification of the enriched population after each round of panning.

Peptides on plasmids are released from cells for panning by gentle enzymatic digestion of the cell wall using lysozyme. After pelleting of the cell debris, the crude lysate can be used directly on most receptors. If some additional purification of the plasmid complexes is needed, a gel filtration column can be used to remove many of the low molecular weight contaminants in the crude lysate.

TABLE 4

Structure	EC50(nM) Proliferation	EC50(nM) Microscopy	IC50(nM)
<p>(H) - (Pen)ADGPTLREWISF(Cys) - (NH₂) (SEQ ID NO:172)</p> 	++	++	++
<p>(O=C-NH) - ADGPTLREWISF(Cys) - (NH₂) (SEQ ID NO:173)</p> 	++	++	++
<p>(H) - (Homocys)ADGPTLREWISF(Cys) - (NH₂) (SEQ ID NO:174)</p> 	++	++	ND
<p>(O=C-N) - ADGPTLREWISF - (Cys) - (NH₂) (SEQ ID NO:173)</p> 	++	++	++
<p>(H) - (D-Cys)ADGPTLREWISF(D-Cys) - (NH₂) (SEQ ID NO:175)</p> 	++	++	ND
<p>(H) - (Cys)ADGPTLREWISF(D-Cys) - (NH₂) (SEQ ID NO:176)</p> 	++	++	++

Structure

EC50(nM) EC50(nM) IC50(nM)
Proliferation Microscopy

Structure	EC50(nM) EC50(nM) IC50(nM) Proliferation Microscopy
$\begin{array}{c} \text{[H]} - \text{ADGPTLREWISFK} - \text{[NH}_2\text{]} \\ \qquad \qquad \qquad \\ \text{O}=\text{C}-\text{NH} \text{-----} \end{array}$	(SEQ ID NO:182) $\frac{+}{+}$ ND
$\begin{array}{c} \text{[O}=\text{C}-\text{NH}] - \text{ADGPTLREWISF(Cys)} - \text{[NH}_2\text{]} \\ \qquad \qquad \qquad \\ \sim \text{-----S} \end{array}$	(SEQ ID NO:173) $\frac{++}{+}$ ND
$\begin{array}{c} \text{[O}=\text{C}-\text{NH}] - \text{ADGPTLREWISF(Cys)} - \text{[NH}_2\text{]} \\ \qquad \qquad \qquad \\ \text{-----S} \end{array}$	(SEQ ID NO:173) $\frac{++}{+}$ ND
$\begin{array}{c} \text{[HN]} - \text{ADGPTLREWISFE} - \text{[NH}_2\text{]} \\ \qquad \qquad \qquad \\ \text{-----C=O} \end{array}$	(SEQ ID NO:183) $\frac{+-}{+}$ +
$\begin{array}{c} \text{[H]} - (\text{Pen})\text{ADGPTLREWISF(Pen)} - \text{[NH}_2\text{]} \\ \qquad \qquad \qquad \\ \text{S} \text{-----S} \end{array}$	(SEQ ID NO:184) $\frac{+-}{+-}$ ND

EXAMPLE 7

In this example amino acid substitutes at positions
D, E, I, S, or F in the cyclized compound SE2 ID NO:10

C A D G P T L R E W I S F C

|_____|

10 were assayed for EC_{50} and IC_{50} values as described above.
Microphysiometer results are given in parentheses. The
results are summarized in Table 5 below.

TABLE 5

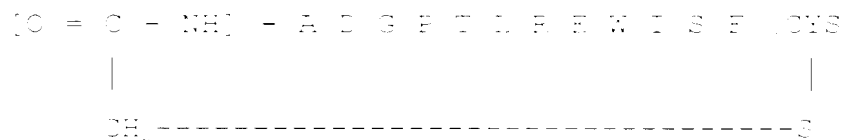
(SEQ ID NO:12)

CADGPTLREWISFC

Substitution	EC50 (nM) Cell Prolif.	IC50 (nM)
E - Q	+++ (+)	++
D - A	÷ (+)	++
I - A	+- (÷)	+
S - A	+++ (÷÷)	+++
S - D-Ala	+	+
S - Sar	+-	+++
S - Aib	++ (+)	+++
S - D-Ser	++	+++
S - Nva	++ (++)	+++
S - Abu	++	+++
S - (N-Me-Ala)	+	+
S - (N-Me-Val)	+	+-
S - (N-Me-Ala) *	+	+-
S - (Nor-Leu)	++	+++
S - (t-Bu-Gly)	+	+++
S - (N-Me-Ser(Bzl))		+

EXAMPLE 8

In this example, amino acid substitutions in the
 5 compound SE₁ ID NO:173

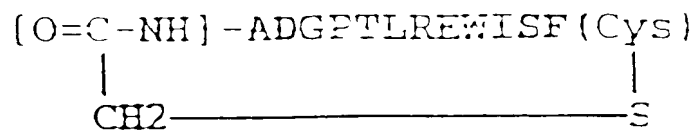


10

were evaluated at positions D, S, or F as indicated in Table 6
 below. EC₅₀ and IC₅₀ values were calculated as described
 above. Microphysiometer results are in parentheses.

TABLE 6

(SEQ ID NO:173)



Substitution	EC50 (nM) Cell Prolif.	IC50 (nM)
D - E	(÷)	ND
free acid form	++ (÷)	ND
C-term. Gly addition	++	++
S - Abu	++ (++)	ND
F - DiPh-Ala	(++)	++
SF - Abu, DiPh-Ala	+(+)	++

EXAMPLE 9

In this example EC₅₀ and IC₅₀ values were calculated as described above for the dimer compounds listed in Table 7 below. The cyclized monomer SEQ ID NO:12

C A D G P T L R E W I S F C

| _____ |

10

is included as a comparison.

The compounds of Table 8 were inactive at the maximum concentration tested of 10um.

In Table 9, EC₅₀ and IC₅₀ values determined as described above for cyclized and dimerized variants of (SEQ ID NO:193)

I E G P T L R Q W L A A R A are compared.

In Table 10, truncations of the dimer (SEQ ID NOS 17 & 18, respectively)

20

(H) - I E G P T L R Q W L A A R A

|

(H) - I E G P T L R Q W L A A R A (βala) K - (NH₂)

are compared. EC₅₀ and IC₅₀ values were calculated as described above. Microphysiometer results are given in parentheses.

TABLE 7

	EC50 (nM)	IC50 (nM)
MicroRNAs	Prolif.	
$\begin{array}{c} \text{O} \\ \parallel \\ [\text{Br}-\text{C}-\text{NH}] - \text{ADGPTLRWISFC} - \{\text{NH}_2\} \end{array}$	(SEQ ID NO:173) ++	++
$\begin{array}{c} \text{O} \\ \parallel \\ [\text{Br}-\text{C}-\text{NH}] - \text{ADGPTLRWISFC} - \{\text{NH}_2\} \end{array}$	(SEQ ID NO:173)	
$[\text{H}] - \text{EEGPTLRQWLAARA}$	(SEQ ID NO:17) ++	++
$[\text{H}] - \text{EEGPTLRQWLAARA}(\beta\text{-Ala})\text{K} - \{\text{NH}_2\}$	(SEQ ID NO:18)	
$[\text{H}] - \text{CEGPTLRQWLAARA} - \{\text{NH}_2\}$	(SEQ ID NO:185) ++	++
$[\text{H}] - \text{CEGPTLRQWLAARA} - \{\text{NH}_2\}$	(SEQ ID NO:185)	
$[\text{H}] - \text{CADGPTLRWISF} - \{\text{NH}_2\}$	(SEQ ID NO:186) ++	++
$[\text{H}] - \text{CADGPTLRWISF} - \{\text{NH}_2\}$	(SEQ ID NO:186)	
$[\text{H}] - \text{SVQCGPTLRQWLAARNHLS} - \{\text{NH}_2\}$	(SEQ ID NO:187) ++	++
$[\text{H}] - \text{SVQCGPTLRQWLAARNHLS} - \{\text{NH}_2\}$	(SEQ ID NO:187)	
$[\text{H}] - \text{FVGPTLRSGC} - \{\text{NH}_2\}$	(SEQ ID NO:188) ND	+
$[\text{H}] - \text{FVGPTLRSGC} - \{\text{NH}_2\}$	(SEQ ID NO:188)	

	EC50 (nM)		IC50 (nM)
	<u>Micrognys.</u>	<u>Prolif.</u>	
<u>CADGPTLREWISFC</u>	(SEQ ID NO:12) +++	++	++
[Ac]-ADGPTLREWISFC	(SEQ ID NO:173) ND	++	++
[Ac]-ADGPTLREWISFC	(SEQ ID NO:173)		
ADGPTLREWISFC	(SEQ ID NO:173) ++	++	++
ADGPTLREWISFC	(SEQ ID NO:173)		
[Ac]-EGPTLREWISFC	(SEQ ID NO:189) ++	++	++
[Ac]-EGPTLREWISFC	(SEQ ID NO:189)		
[Ac]-GPTLREWISFC	(SEQ ID NO:190) ND	++	++
[Ac]-GPTLREWISFC	(SEQ ID NO:190)		
GPTLREWISFC	(SEQ ID NO:190) ++	++	+
GPTLREWISFC	(SEQ ID NO:190)		
[Ac]-PTLREWISFC	(SEQ ID NO:191) ND	++	++
[Ac]-PTLREWISFC	(SEQ ID NO:191)		
PTLREWISFC	(SEQ ID NO:191) ++	++	+
PTLREWISFC	(SEQ ID NO:191)		
[Ac]-TLREWISFC	(SEQ ID NO:192) +	+	+
[Ac]-TLREWISFC	(SEQ ID NO:192)		
TLREWISFC	(SEQ ID NO:192) ++	+	+
TLREWISFC	(SEQ ID NO:192)		

TABLE 8

(SEQ ID NOS 205-222, respectively)

[H]-CTFAQFLNGC-(NH₂)[H]-CHINQLESTC-(NH₂)[H]-CNRSQLLAAC-(NH₂)[H]-CTSTQWLLAC-(NH₂)[H]-CQRADLINFC-(NH₂)[H]-CLLSEFLAGQOC-(NH₂)[H]-CTFQVWKLARNC-(NH₂)[H]-CTLGQWLQHGEC-(NH₂)[H]-CLTGFVVTQWLYEC-(NH₂)[H]-CTLREFFDPTTAVC-(NH₂)[H]-CGTEGPTLSTWLDC-(NH₂)[H]-CELVGPSLMSWLTC-(NH₂)[H]-CELKGFLEHSGLAQC-(NH₂)[H]-CTLAEFFLASGVEQC-(NH₂)[H]-CTLKEWLVSHEVWC-(NH₂)

TABLE 9

	EC50 (nM)	IC50 (nM)
	<u>MicroRNVS</u>	<u>Prolif.</u>
[H]-IEGPTLRQWLAA ^{RA} -(NH ₂)	(SEQ ID NO:193) N.D.	++
[H]- <u>CEEGPTLRQWLAA^{RA}AC</u> -(NH ₂)	(SEQ ID NO:194) N.D.	++
[H]-IEGPTLRQWLAA ^{RA}	(SEQ ID NO:17)	++
[H]-IEGPTLRQWLAA ^{RA} (β-Ala)K-(NH ₂)	(SEQ ID NO:18)	++
[H]-CEEGPTLRQWLAA ^{RA} -(NH ₂)	(SEQ ID NO:185)	++
[H]-CEEGPTLRQWLAA ^{RA} -(NH ₂)	(SEQ ID NO:185)	++

TABLE 10

(H)-IEGPTLRQWLAARA

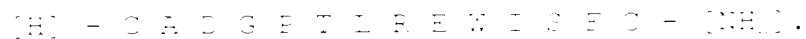
(H)-IEGPTLRQWLAARA(β -Ala)K-(NH₂) (SEQ ID NOS 17 & 18)

Sequence	EC50 (nM) Cell Prolif.	IC50 (nM)
(Ac)-IEGPTLRQWLAARA (Ac)-IEGPTLRQWLAARA- β A-K(NH ₂) (SEQ ID NOS 17 & 18)	++	ND
(H)-IEGPTLRQWLAAR (H)-IEGPTLRQWLAAR- β A-K(NH ₂) (SEQ ID NOS 195 & 196)	++	ND
(H)-IEGPTLRQWLAA (H)-IEGPTLRQWLAA- β A-K(NH ₂) (SEQ ID NOS 197 & 198)	++(++)	ND
(Ac)-EGPTLRQWLAARA (Ac)-EGPTLRQWLAARA- β A-K(NH ₂) (SEQ ID NOS 199 & 200)	ND	ND
(H)-EGPTLRQWLAARA (H)-EGPTLRQWLAARA- β A-K(NH ₂) (SEQ ID NOS 199 & 200)	++	ND
(H)-EGPTLRQWLAAR (H)-EGPTLRQWLAAR- β A-K(NH ₂) (SEQ ID NOS 201 & 202)	++(++)	ND
(Ac)-EGPTLRQWLAA (Ac)-EGPTLRQWLAA- β A-K(NH ₂) (SEQ ID NOS 203 & 204)	+-	ND
(H)-EGPTLRQWLAA (H)-EGPTLRQWLAA- β A-K(NH ₂) (SEQ ID NOS 203 & 204)	+-	ND

14
EXAMPLE 10

In this example various substitutions were introduced at positions G, P, and W in the cyclized compound

8 SEQ ID NO:10



10 Table 11 lists examples of the substituted compounds that show TPO agonist activity. The substitutions abbreviated in the table are as follows:

TABLE 11

15

[H] - C A D G P T L R E W I S F C - [NH ₂]		
G	P	W
Sar	Hyp(OBn)	Nal
Sar	Hyp(OBn)	Nal
Gly	Pro	Trp
Gly	Pro	Trp
Sar	Hyp(OBn)	Nal
Gaba	Pro	Trp
Cpr-Gly	Pro	Trp
Sar	Hyp(OBn)	Nal
Gly	Pro	Trp
Gly	Pro	Nal
Sar	Pro	Trp
Cpr-Gly	L-Tic	Nal
Gly	D-Tic	D-Trp
Cpr-Gly	D-Tic	Trp
Gaba	Hyp(OBn)	Trp